THE USE OF THE WORD "RESILIENCE" IN FOREST AND FIRE MANAGEMENT AND SCIENCE IN THE WESTERN UNITED STATES

By

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Abstract

The word “resilience” is increasingly used in the context of federal forest and fire management and science in the western United States, but how it will be operationalized remains uncertain. Those who use, or advocate use of the word, suggest it represents a useful concept for sustainably managing forests in the face of uncertain environmental changes. Some critics of the word argue its meaning is too subjective for effective planning and that it may only be a comforting buzzword. The objective of this study is to explore the use of the word “resilience” (i.e. resilience, resilient, and resiliency) in forest and fire science and management contexts by looking beyond academic and technical definitions to the context of its use over time. I perform a computer-aided content analysis and structural topic modeling of 1,487 scientific articles on western forests and fire, and 139 western-based U.S. Forest Service planning documents to answer three questions: (1) How has “resilience” use changed over time? (2) Are changes in the use of “resilience” associated with shifts in terminology related to environmental values, complex systems theory, or climate change? And, (3) how does the use of “resilience” between scientists, and the scientific literature; and USFS mangers, and USFS management documents, compare? To ground my interpretations in the context of the term’s use, I also conduct 25 semi-structured interviews with scientists and managers across the region. The results of this study show that “resilience” has been used in these documents since the 1980s, but saw a rapid increase in both contexts between 2009 and 2011. In both USFS and science documents resilience use, is not associated with changes in the use of utilitarian or biocentric value terms, but most associated with changes in the use of the words “climate change” and “adapt.” The implications of “resilience” for federal forest management are still emerging and will change as the word takes on new meanings.

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Finally, I must acknowledge the role of everyone who took the time to speak with me, but remain anonymous in these pages. I greatly appreciate the conversations I have had with USFS managers and scientists working across the western United States concerned about the future of the nation's forests. My hope is that this work addresses these concerns and can contribute in some small way to the communication between people who share them.

Chapter 1: Introduction

> I have tried to develop senses that help me listen to intriguing voices that are hidden amongst the noise … it was a way to listen to the hidden voice of nature. Those voices led to the discovery of resilience. Not a song but a symphony!
>
> —C.S. Holling, (2006) from an online memoir of the academic scientist credited with first defining resilience for ecological systems

> What the hell does that mean for active managers? It's one thing to be thinking about resilience in academia, but we're being asked right now to put that in place.
>
> —Federal land manager, Missoula 2017, in response to "what is resilience?"

This study is part of a Joint Fire Science Program (JFSP) interdisciplinary project with the aim of 'operationalizing' the concept of resilience for forest management in the North Rockies region of the United States. The principal goal of the project was to identify and then quantify, the ecological and social aspects of "resilience" in the Northern Rocky Mountain forest. Once collected, this information was to be used as inputs for a region-wide forest simulation model. I joined the project as a Master's student in the summer of 2016 under the direction of Dr. Adena Rissman to research the social aspects of resilience. The simple question *what does resilience mean*? was the seed for the manuscript that follows.

Resilience is widely discussed across a variety of academic literatures, but its meaning for land management remains open. The confusion over its meaning can be traced back to its first use by C.S. Holling in 1973, who defined resilience in two ways, later noting that each definition reflected "traditions of a discipline or of an attitude more than of a reality of nature" (Holling 1973, 2001). To me, this suggested that the confusion over resilience might be less about definitions, and more about the concerns, goals, attitudes, or values, behind its use. The 2016 JFSP funding opportunity notice was interested in "projects that explore and better define the concept of resilient landscapes, especially considering changing climates" and one reason for this was to provide analyses to support The National Cohesive Wildland Fire Management Strategy, which sets a goal to "restore and maintain landscapes… [that] are resilient to fire-related disturbances in accordance with management objectives" (U. S. Department of Agriculture and Interior 2011; Cissel and Jenison 2015). With "resilience" as a central component of this policy, a careful consideration of the word's *meaning* for land management is an integral part of this work.

In February of 2017 our research team held two workshops in Montana with managers and scientists from the northern Rocky Mountains region. Land managers had specific concerns that were driven by public opinions and policy debates. Scientists were looking for social and ecological factors to incorporate into an innovative forest-simulation model. Both expressed concern about how the forests of the region might change in the future. Our survey of both participants and the scientists on our team suggested that scientists and managers defined the word resilience similarly, but that there were subtle and potentially significant, differences between their concerns, strategies, and goals. In informal conversations with managers during these workshops I heard concerns about the ambiguity of resilience when applied to management. If the definition of a term is shared across groups who use it, why might the underlying meanings differ? Since federal land management depends on communicating values and strategies between scientists, managers, policy makers, and the public, considering the *reasons* and implications for this ambiguity deserves further attention.

During the summer and into the fall of 2017, I began to explore the use of the word "resilience" by experimenting with tools for textual analysis, developed in a branch of computer science and machine-learning, called natural-language processing (NLP). With these tools, text can be treated like quantative data— parsed, tagged, normalized, and analyzed for meaningful patterns. If the meaning of resilience was not shared, could I devise a way to detect and understand differences in written documents? At first, I approached this question by training a machine-learning model to classify thousands of uses of resilience into conceptual categories that are described in the academic literature, i.e. engineering and ecosystem resilience (see Brand and Jax 2007). However, when I asked other forestry and natural resource policy graduate students to help me assess the reliability of these categories, we struggled to come to a consensus about their boundaries. The precise of meaning of "resilience" my model required kept slipping away. This problem led me to a body of literature in philosophy and linguistics that challenged both this quantative and deductive methodology, and, my entire understanding of language itself.

In his effort to address the ambiguity of "sustainability," the philosopher Bryan Norton, argued that the reason for frequent disagreements over terminology in land management is an underlying assumption that the meaning of words is inherent to their written or spoken signifier—a view of language that philosophers call "essentialism." Language, in this view, is linked to an external and unchanging reality or structure of the world, in which each word represents an unchanging and real category of meaning. Norton, along with many linguists and philosophers of language, reject this static view of language for a "conventionalist" one, where language is dynamic and evolving. *Meaning* in this view is never inherent to a word, but depends on the context of its use and collective interpretation (Norton 2005). Adopting the conventionalist view of language suggests that to understand what resilience means for federal forest and fire management, we cannot only focus on bounded definitions, or conceptual categories created in the academic literature, but we must also look for those categories in written and spoken language.

Language is all around us and changes over time—notions easily taken for granted, but essential for understanding how terminology changes in science, management. Resilience is increasingly popular in ecology, but also in psychology, urban planning, disaster management, and public health, which suggests that it might be part of a much broader social, cultural, and economic phenomenon. Reflecting carefully on the use and meaning of words is important especially when we need to communicate clearly about what we value. In this study I attempt to explore the meaning of resilience for forest and fire science and management by looking beyond definitions to its use over time through a content analysis of scientific and management documents as well as semi-structured interviews with scientists and managers. I hope that this work will encourage a discussion among scientists and managers about the underlying meanings of resilience, but more importantly, about the important role of language in science and public land management.

Chapter 2: A Content Analysis of the Use of "Resilience" in Forest and Fire Management and Science in the Western United States

> The meaning of a word is its use in language… don't think, but look!
>
> — Ludwig Wittgenstein, *Philosophical Investigations*

> Some people, when they see a word, think the first thing to do is to define it… for words of a different kind, and especially for those which involve ideas and values, it is not only an impossible but an irrelevant procedure.
>
> — Raymond Williams, *Keywords: A Vocabulary of Culture and Society*

1.1 Introduction

As new scientific terms gain prominence in land management policy and scientific writing, the social and historical context of their use is critical for their interpretation (Skillen 2015; Norton 2005; Klyza 2000). Among scientists, disagreements over the meaning of scientific terms are common in land management. Debates surrounding the use of terms like "keystone species", "sustainability," "ecosystem management," "integrity," and "new forestry" (Davic 2003; Grumbine 1994; Gillis 1990). In the United States, federal land management agencies like the United States Forest Service, National Park Service, and Fish and Wild Life Service, are required by law to balance competing interests while integrating the "best available science" into decision making, but significant policy debates surround the choice of management strategies and of language (Wright 2010; Hays 2006). Underlying these debates about management and terminology, are clashes between conflicting values and beliefs regarding the purpose of public land. The possibility of transparent and equitable federal land management depends on the communication of environmental values between policy makers, managers, scientists, and the public; and therefore, a common language and vocabulary (Turner 2012; Langston and Cronon 1996).

Managing fire has long been a central issue for the western US federal land management, but the increasing frequency and costs of wildfire are pushing agencies to reconsider the long-practiced strategy of fire suppression (Pyne 1997; Stephens and Ruth 2005; Dellasala et al. 2004). In recent years, the word "resilience" has increasingly appeared in discussions about a national federal United States wildfire policy. It has been variously used to describe a management strategy for adapting forests to climate change; a national goal of learning to adapt and "live with wildland fire;" and, in a recently passed law (H.R. 1625), as a goal for expedited "fuel reduction" projects (Millar, Stephenson, and Stephens 2007; Moritz et al. 2014; U. S. Department of Agriculture and Interior 2011). In ecology, the word resilience is often associated with a theoretical concept developed in the 1970s that has also been called by its primary theorists, a "metaphor" or even a "way of thinking." But, as soon as the word entered ecology, its meaning for land management was subject to debate (Carpenter et al. 2001; Folke 2016; Brand and Jax 2007).

Holling, credited with introducing the word to ecology, was the first to use define resilience in multiple ways (Holling 1973, 2001). Rather than merging into a unified concept over time, the term has acquired a multitude of meanings, and the debate has carried on into current land management policy briefs and technical reports on US wildfire policy (Timberlake, Schultz, and Abrams 2017). Advocates and critics of the word alike have demonstrated that the way it is defined will have "major consequences for policy" (Holling and Meffe 1996; Newton and Cantarello 2015). Scholars and managers frustrated with the ambiguity of the term have even called it "maladaptive" in that it can simultaneously imply "diametrically opposed" management strategies, ranging from historical restoration to a transition to ecosystem novelty (Fisichelli, Schuurman, and Hoffman 2015; Newton 2016). Furthermore, the dictionary definition of resilience, most likely used by the public, might imply resistance to environmental changes, which is far from the transformational and often controversial management strategies called for in the face of climate change (Millar, Stephenson, and Stephens 2007).

In this study, I look beyond the academic and technical definitions of resilience to analyze its use in the context of the United States Forest Service (USFS) and forest and fire science in the western United States. The USFS manages over 193 million acres, is the oldest federal land management agency in the United States, and has been at the center of some of the country's most significant environmental controversies (Steen 2004). The majority of USFS land (~80%) is in the western states where fire management has been one the most important issues (Vincent, Hanson, and Bjelopera 2014; Pyne 1997). The USFS has also been the most proactive federal land management agency in adopting "resilience" into management and planning documents (Benson and Garmestani 2011). In a recent content analysis study of USFS documents, Bone et al. found that "resilience" is increasingly used in high level planning documents and yet "requires conceptual clarity" (Bone et al. 2016). I build on this analysis by applying the methods of computer-aided content analysis, structural topic modeling, and semi-structured interviews to take a broad look at how the word "resilience" (i.e. resilience, resilient, and resiliency) is being used in context of western United States Forest Service planning and western forest and fire management science. Specifically, I explore resilience use across USFS planning and management documents and western forest and fire scientific articles, to answer the following questions:

1. How has the use of the word “resilience” changed over time?
2. Are changes in the use of “resilience” associated with shifts in terminology related to environmental values, complex systems theory, or environmental change?
3. How does the use of “resilience” in scientific literature and USFS planning documents compare?

1.2 Language in science, management and policy

With a call to operationalize resilience for management, scientists have addressed the problem of defining resilience by focusing on two explanations for its ambiguity: (1) theoretical complexity and (2) interdisciplinary use. Holling’s original use of the word was to distinguish his theory of ecosystem stability that emphasized *complexity*, *dynamism*, and *unpredictability* from the classical notion of stability characterized by *simplicity*, *predictability*, *equilibrium*. This only added it to a list of other so-called stability terms like “elasticity”, “resistance”, “persistence”, and “constancy (Holling 1973; Grimm and Wissel 1997). To manage the ambiguity of stability terms, some scholars have recommended carefully specifying them to their ecological context, like Carpenter et al., who most influentially recommended defining resilience by asking “resilience of what?” and “resilience to what?” for each situation in which it is applied (Carpenter et al. 2001). Another explanation for the ambiguity of resilience is that it is highly interdisciplinary. It has been widely adopted across academic literatures, including psychology, urban planning, disaster management, and public health, and acquires a new definition for each disciplinary context in which it is used (Baggio, Brown, and Hellebrandt 2015). To keep track of this ‘multitude of meanings’ some have created comprehensive typologies that define its use for each disciplinary context (Davidson et al. 2016; Brand and Jax 2007).

These approaches to defining resilience recognize that the term’s meaning depends on the the ecological and academic context of its use, but do not consider the medium of language itself as a source of confusion. In an effort to address the ambiguity of another notorious term, “sustainability,” the philosopher Bryan Norton, has argued that the underlying reason for frequent disagreements over terminology in land management, is an underlying assumption that the meaning of language is inherent to its written or spoken signifier (i.e. words)—a view of language that philosophers call ‘essentialism’. In this view language represents an external and unchanging reality or structure of the world, in which words represent an unchanging and objective categories of meaning. Norton, along with many linguists, philosophers of language, and social scientists reject this static view of language for a ‘conventionalist’ one, where language is dynamic, evolving, and not ‘essential’, but based on social convention. Meaning in this view is never inherent to a word, but depends on the context of its use and its collective interpretation, because, as Norton explains: “language gains meaning from the dynamic relations emerging within a constantly changing and evolving culture composed of purposeful individuals in linguistically cohesive communication” (Norton 2005)

Reconsidering language as social convention, rather than a representation of an objective scientific reality opens alternative approaches to understanding ambiguity and the meaning of scientific terminology. For example, in *Keywords: A Vocabulary of Culture and Society* the literature theorist Raymond Williams, who pioneered the study of words as social and cultural products, explores a number of ambiguous words including, “nature,” “culture,” and “society,” and the social and cultural processes that contribute to their changing meanings (Williams 1985). Another approach called ‘discourse analysis’ seeks to understand the role of language in environmental policy in producing and reproducing social relations. In this view the meanings of words and scientific concepts “are not and cannot be imposed in a top-down way … but are are continually contested in a struggle about their meaning and interpretation” (Hajer and Versteeg 2005). Walker and Cooper have applied this this approach to examine how “resilience” as a discourse has become a “pervasive idiom of global governance” and is tied to “logistics of crisis management, financial (de)regulation and development economics” (Walker and Cooper 2011). McGreavy’s study of “resilience” as discourse explores the word as what she calls a “frame” used by the media, organizations, and governments to imply “resistance, control, and attempts to return to normalcy” and developed by academics who advocate “specific ways of understanding, measuring, visualizing, and otherwise ordering reality” (McGreavy 2016).

The idea of resilience as a frame that can advance a particular “ordering of reality” is related to an approach to studying language, developed and applied in psychology, sociology, linguistics, and political communication studies generally know as “framing theory.” Framing theory openly acknowledges that “the production of reliable knowledge about the natural world has always been a social and political endeavor” and seeks to examine how language is used as a tool for scientists, government agencies, and mangers to “frame” facts, actions or intentions (Scheufele 2014). According to the developers of framing theory, language—metaphors, words, and rhetoric—are not representations of objective reality, but instead are the building blocks of frames, or “primary frameworks,” that are used by people to understand and interpret reality and learn new information (Goffman 1974; Lakoff and Johnson 2003).

Politicians have taken advantage of these research by strategically using language to frame information to achieve desired policy outcomes (Scheufele 2014). The Bush Administration’s effort to pass the Health Forests Act of 2005 is a well illustrated example how environmental events (wildfires) and scientific concepts (forest health) have been re-framed to influence public perceptions of federal forest policy (Vaughn and Cortner 2005). Furthermore, frequently used, but ambiguous management terms, like sustainability, health, integrity, and resilience have been criticized for their ambiguity, and called “buzzwords,” but these kinds of words are far from meaningless. Organizational and development scholars have identified these words as “management buzzwords”, ambiguous but optimistic terms, that managers can use to establish authority, conceal sensitive issues, and displace responsibility (Cornwall 2007; Cluley 2013). In the polarized context of environmental policy, ambiguous words or phrases may be useful if they can obscure controversial intentions (Fisichelli, Schuurman, and Hoffman 2015; Edelman 1977; Burke 1969).

Ultimately, approaches to understanding scientific terminology that rely on a ‘conventionalist’ view of language all suggest that the best approach to understanding an ambiguous term in the context of USFS forest management and science should not focus on definitions. Instead, it requires an inductive social, historical, or textual analysis of the its use in written and spoken language. The study of language and changing management paradigms is usually conducted through careful readings of primary documents and presented through historical narrative, however the ability of computers to detect and quantify patterns allows for a closer examination of specific words or phrases across much larger bodies of text. Computer-aided content analysis is an established methodology for systematically drawing inferences from text that can (1) vastly increase the number of documents examined; (2) track patterns over time; and (3) evaluate small, but important differences, between contexts (Krippendorff 2012). In the field of natural resources computer-aided content analysis has been applied in variety of ways including an analysis of research topics (Nunez-Mir et al. 2017) and changing environmental values (Bengston and Xu 1995; also see Bengston 2000).

In this study I adopt a methodological framework for content analysis that considers meaning as distinct from both a text and its source. This implies that meaning cannot be measured from a text, but must emerge from the “process of a researcher analyzing text relative to its particular context” (Krippendorff 2012). Therefore, to ground my interpretations of the text to the particular context of its use, I also conducted telephone semi-structured interviews of scientists and USFS managers who are representative of the people reading and writing the documents I analyzed. In the following section I review the contexts I hypothesize to be important for the changing use of resilience in USFS forest management and planning and western forest and fire science between 1980 and 2016. These include complex systems science, environmental values, environmental change, and USFS management and planning policy.

1.3 Context

1.3.1 Science of complex systems

The word “resilience” was introduced to ecology in 1973 by C.S. Holling. In the early 1990s and 2000s a group of scientists—led by Holling, Elinor Ostrom, Steve Carpenter, Lance Gunderson, Carl Folke and Fikret Berkes and others—developed a conceptual framework around the word based on the theory that reducing the hierarchical control of complex ‘social-ecological systems’ might allow for the self-organization of “polycentric systems of governance” that are diverse, sustainable, and resilient to unexpected changes (Folke 2006; Ostrom 2009; Gunderson and Holling 2002; Berkes, Folke, and Colding 2000). In place of traditional natural resource management, what Holling called a “command and control pathology”, they argued that this “resilience approach” would place more emphasis on the “flexibility of institutions, and incentives in economics” to encourage more sustainable resource management (Holling and Meffe 1996; Gunderson and Holling 2002). This group of scholars formalized into an organization named the Resilience Alliance in 1999 (www.resalliance.org), and, in the last decade, their conceptual apparatus centered around the concept of resilience has become a “dominant discourse in natural resource management” (Walker and Cooper 2011; Parker and Hackett 2012).

The Resilience Alliances’ use and conceptualization of resilience, however, can be placed in a much broader economic and cultural shift in postwar science toward inter-disciplinary research, computer simulation, and complex systems theory, with latter ascending to become a unifying paradigm for a wide range of academic fields including psychology, sociology, biology, physics, and ecology (Grauwin et al. 2012). Prior to the 1950s, the predominant view of nature held by U.S. ecologists was that it was inherently balanced, stable, and held a single-equilibrium; a view strongly characterized by the theory of succession and the idea of a “balance of nature,” but the perspective of complex systems theory has challenged these notions by re-theorizing ecosystems as complex, dynamic, and non-linear systems characterized by multiple equilibriums, self-organization, networks, and adaptive learning (Barbour 1996; Turner 2014; Worster 1994). The simultaneous increase in computing power has also opened the door for ecologists to transcend, what might have been, impenetrable complexity, by simulating and modeling ecosystems in search of emergent patterns and properties across space and time (Levin 1998; May 2001). Recent reviews and applications of resilience theory continue to emphasize the importance of complex systems theory (Messier et al. 2015; Lindenmayer, Messier, and Sato 2016).

1.3.2 Environmental values

Perceptions of forests and forest management in the United States have evolved over time, but are typically described by historians and environmental policy scholars as interrelated, as well as shaped by the dominant environmental values held at the time (Williams 1992; Dana and Fairfax 1980; Steen 1999). During the 1960s and 1970s the United States went through what is often called the “environmental movement” which historians and social scientists have often connected to a corresponding shift in public values from a more economic, or utilitarian view, toward a more intrinsic, ecological, view of nature (Hays 2006, 1987; Nash 2001). Social scientists who study environmental values have typically called these two value orientations, or “philosophical and normative views of forests” the anthropocentric view and biocentric view, respectively (Steel, List, and Shindler 1994; Vaske et al. 2001). Although their motivations may differ, those who hold the biocentric view typically see nature as holding intrinsic or life sustaining value and emphasize the interconnectedness of human society with the environment, while those who hold the utilitarian view emphasize economic development (Bengston, Webb, and Fan 2004). The ambiguity of the term resilience, however, suggests that it could be employed by policy makers, managers, and scientists to frame management goals as supported by either view (Newton 2016).

1.3.3 Environmental changes

The use of resilience began, and has increased, as scientists and managers have become increasingly concerned about dramatic and sudden environmental changes. Holling's early work argued that managing for resilience rather than stability could avoid ecological collapse caused by misguided management and human population growth (Holling and Meffe 1996). More recently, the discussion has shifted to considering climate change and increasing human development as the primary drivers of 'ecological novelty', and 'catastrophic' environmental changes, and ecosystem 'collapse' (Radeloff et al. 2015; Folke et al. 2004). In the western United States this conversation has been centered on the role of climate change in the increasing frequency and severity of wildfire and the ability of policy and management paradigms to adapt (Moritz et al. 2014; Stephens et al. 2013). Key studies on the relationship between warming and fire in the western United States have found that it climate change could have "profound consequences for many species and for ecosystem services including aesthetics, hydrology, and carbon storage" (Westerling et al. 2011, 2006; Abatzoglou and Williams 2016; Harvey 2016). In this context, scientists have proposed that resilience offers a balanced approach to management in the face of climate change that looks to the past, but prepares for the future (Millar, Stephenson, and Stephens 2007; Adger et al. 2011; Nelson, Adger, and Brown 2007), but critics of resilience argue that the ambiguity of the term makes it more "maladaptive" than adaptive (Fisichelli, Schuurman, and Hoffman 2015).

1.3.4 USFS Management and planning

The USFS manages land in units called national forests and grasslands. Early on the agency was directed by the Organic Act 1897 to focus on supplying a sustainable source of timber and water, but conflicts between competing public interests, particularly grazing, and a growing demand for recreation in the 1950s, intensified and eventually led Congress to pass the Multiple-Use and Sustained Yield Act (MUSYA) in 1960. MUSYA formally mandated that the USFS land be managed to balance public interests—timber, recreation, mining, and grazing—in a "harmonious and coordinated" manner while extracting resources at the highest level possible for a "sustained yield," a paradox central to the contentious nature of USFS management since (Dana and Fairfax 1980; Hirt 1996). Changing attitudes toward the responsibility of government and the growing power of the environmental movement during the 1960s and 1970s brought new laws and significant changes to how public lands were managed. The National Environmental Policy Act (NEPA) of 1969 required all federal agencies, including the USFS, to produce Environmental Impact Statements (EIS) before actions and important plans. The National Forest Management Act of 1976 (NFMA), was passed following controversy and lawsuits surrounding the practice of clear-cutting on national forests, and required every USFS unit to develop Land Management Plans (LMP), or Forest Plans (FP), for guiding management. In 1982 a Planning Rule (known as the 1982 Planning Rule), stipulated the development of these plans would require an interdisciplinary and collaborative process. The legacy of NEPA (1969), NFMA (1976) and the 1982 Planning Rule was that USFS land management was required to be evidence based, interdisciplinary, and include public participation. Between the early 1980s and 1995 every existing National Forest unit developed an FP under the process defined in the 1982 Planning Rule and developed the corresponding EIS document mandated by NEPA.

In the 1990s, USFS land management policy was driven by the appeals process and frequent litigation, but particularly the priorities of presidential administrations that have the power to staff agencies and set the policy agenda. A new paradigm called "ecosystem management" promised to bring opposing viewpoints (utilitarian and biocentric) together, but was used by the Clinton administration (1993-2001) to promote policies with biocentric leanings, like the Northwest Forest Plan (NWFP) of 1994, which contains only a single use of the word 'resiliency' in relation to "riparian and aquatic ecosystems" (Skillen 2015). The Bush administration (2001-2009), on the other hand, re-framed existing paradigms and scientific language to advance utilitarian interests, notably in the Healthy Forest Act (HFA) of 2003 in which the resilience occurs seven times in relation to 'wildfire-resilient stands' and resilience to insects (Vaughn and Cortner 2005). During the early years of the Obama administration, a major revision to the 1982 Planning Rule was developed and approved in 2012. In the initial draft of this rule the word resilience appeared frequently, often paired with "ecosystem health" and was used in the context of wildlife, wildlife habitat, viable populations, watersheds, and aquatic ecosystems. However, the term was mostly removed from the final version, because of, as it was explained in the agency's response to public comments, "public concern about how to define and measure" resilience.

1.4 Methods

1.4.1 Document collection

To gather the text representative of USFS management and planning I downloaded PDFs of all available Forest Plans (FP) and Federal Environment Impact Statements (FEIS) from the websites of all National Forests and Grasslands located in the western U.S. (Washington, Oregon, California, Nevada, Idaho, Montana, Wyoming, Utah, Arizona, New Mexico, and Colorado). Units that have updated or revised their original FPs may have up to two of each document type. I identified a total of 78 units in these states and 75 had at least one document available for download. Documents were occasionally missing or failed to download. The final number of PDFs collected was 1072, which, because a single document could be composed of multiple PDFs, represents 98 LMPs and 51 FEIS documents.

To gather the text representative of forest and fire management science, I gathered scientific journal articles by querying the Web of Science database for journal articles published between 1980 and 2016 that included the terms "forest*" AND* "fire", AND "manage*" (the asterisk represents a wildcard) in their title or abstract; and, had at least one author-affiliated with the United States. This query returned 3225 references including 41 book chapters that were removed leaving a total of 3184 articles. To limit these to the western United States, I removed articles that did not contain the name of a western state or USFS unit in the abstract or title, which left a total of 1527 articles. Using EndNote's "find full-text" feature I downloaded 672 of these documents as PDFs. The remaining 824 articles were downloaded manually and 31 articles could not be found online. The final count of relevant journal articles was 1496.

PDF documents from each context were converted into raw text and pre-processed using open-source tools for text analysis. Scientific journal articles, which have a relatively predictable text structure were converted into raw text using GROBID, a tool developed explicitly for this purpose (Lopez 2009). Nine documents failed to convert leaving a total of 1487 documents for analysis. Forest Plans and FEIS documents were converted into raw text using Python's PDFminer 1.3.1. All USFS budget justifications were converted successfully, but 10 complete USFS management documents failed to convert leaving a total of 91 Forest Plans and 48 FEIS for analysis. I used the Python's Natural Language Toolkit 3.2.1 (NLTK) to remove common words, i.e. stopwords ("and", "the", "or", etc.), and singularize words (e.g. "trees" converted to "tree") (Bird, Klein, and Loper 2009). Words were not stemmed or lemmatized, other common normalization methods for reducing inflected words to their stem, to improve the interpretability the results (Bird, Klein, and Loper 2009).

Table 1: Document and token count summary by context and document type

Context	Type	Number of Documents	Processed Word Count
USFS planning	Forest Plan	91	8,243,141
	FEIS	48	12,280,307
Science	Journal Article	1,487	5,011,157
Total		1,626	25,534,605

1.4.2 Semi-structured interviews

To position my interpretations of the text to the context of its spoken use, I conducted semi-structured interviews with scientists and USFS managers. I selected and emailed thirty-five scientists working in the western United States who had authored the highest number journal articles in Web of Science that included the terms "forest", "fire", AND "resilience." I emailed 104 USFS employees working in

Western regions in positions relevant to planning and management (i.e. Forester, Fire Ecologist, NEPA Planner, etc.) listed in the USFS employee database. Semi-structured interviews were conducted over the phone (Appendix D) using a dramaturgical approach. The interviews were recorded with the permission of participants and transcribed and reread (Berg and Lune 2011). I continued conducting interviews until saturation. In total, I conducted 25 interviews: 11 with university and USFS scientists and 14 with USFS managers.

1.4.3 Analysis

To answer Q1 I compared the resilience use rate trend by context and year of publication. This was calculated by dividing the total number of resilience instances that occurred in a context each year (i.e. resilience, resilient, resiliency) by the total number of words for that context and year. To answer Q2 I compared the resilience use rate trend to trends in the rate of terms in coding dictionaries that represent contextual categories of meaning hypothesized as important factors of resilience use: environmental values, complexity science, and environmental change (for a review of "coding dictionaries" see Krippendorff 2012). The dictionaries for utilitarian and biocentric environmental values were drawn from a previous content analysis of forest values (Appendix B). Because the length of these two coding dictionaries differ, their rates were weighted as a proportion of the combined count of terms in both dictionaries. The dictionary for complex system theory was derived from a list of terms used in a bibliometric study on complex system research (Appendix B). The dictionary for environmental change focused on climate change adaptation and only include the terms "climate change" and "adapt." Thirty-one multivariate regression models were fitted to the data of each context using Python's statsmodels 0.8.0. to estimate the resilience rate by year using every possible combination of independent variables (i.e. biocentric term rate, utilitarian term rate, complex systems term rate, climate change adaptation rate, as well as the single time-period lagged resilience rate). For each context the model with the lowest Akaike information criterion (AIC) score (the 'Best fit') and the 'complete' model were evaluated and compared.

To answer Q3 I fit and evaluated a structural topic model (STM) on every instance of resilience (i.e. resilience, resiliency and resilient) extracted from documents using a 10-word context window (10 tokens to the left and 10 tokens to the right). An STM is an unsupervised, machine-learning algorithm used for inferring and comparing themes, or "topics," in large collections of documents (Roberts, Stewart, and Tingley 2017). This approach is useful for comparing language between two contexts and has been applied in a wide variety of comparative studies of text (Lucas et al. 2015; Bohr and Dunlap 2018; Chandelier et al. 2018; Rothschild et al. 2018). The contextual words around resilience (10-words on both sides) were converted into a numerical feature vector using the "bag of words" approach (Bird, Klein, and Loper 2009). Prior to fitting the model, I also computed phrases—two words that frequently co-occur together across instances, like "climate change" or "insect outbreak"—to include as unique terms in the vector representation of each instance of resilience using gensim's Phrase collocation detection class (Řehek and Sojka 2010). Rather than providing a prior number of topics to discover, as topic models usually require, I used a model initialization method for inferring the optimal number of topics (Lee and Mimno 2017). The results of the topic model are algorithmically inferred collections of words that are both shared and distinctive to scientific journal articles and USFS planning documents (Blei, Ng, and Jordan 2003).

1.5 Results

1.5.1 Q1: Resilience use over time

Plotting the trends of resilience use over time reveals that term has been nominally present in both USFS planning documents and scientific journal articles since the 1980s (Figure 1). The earliest use of resilience in USFS planning documents was in the early 1980s and about the response of areas, streams, and vegetation to recreation impacts; and, the effects of economic diversification. The first occurrence of resilience in the western scientific literature of forest and fire management in this dataset appeared in 1993 in an economic analysis of ungulate herbivory (Weigand et al. 1993). After 1993 the use of resilience leveled out until about 2011 when the use of resilience increased sharply in both USFS planning documents and scientific journal articles. Resilience has not replaced other noted terminology, like "health" or "integrity" (Table 1).

In interviews, USFS managers told me that although they have heard the term used for a long time, its use has become much more frequent in the last 5-10 years. Most USFS managers were first exposed to resilience though scientific training, work on a project, grant writing, or a supervisor. Explanations for the recent increase in the use of the term vary, but many managers saw the increased use of resilience because of a direct policy action, like the development and implementation of the Northwest Forest Plan in the early 1990s, the Healthy Forest Initiative in the mid-2000s, the 2012 Planning Rule, or the Executive Order 13653 signed by President Obama in 2013. Scientists, on the other hand, generally described resilience usage beginning as a theoretical discussion in the early 1990s with recent efforts to formalize the concept for management. Unlike USFS managers, scientists did not see the recent increase in resilience use as having a policy origin; rather, the increase in resilience use in management was typically described as "bubbling up" into policy. Millar et al. 2007 (see bibliography) was frequently mentioned as a key scientific paper. Several scientists mentioned the work of C.S. Holling and a few speculated directly about the role of the Resilience Alliance in promoting use of the term.

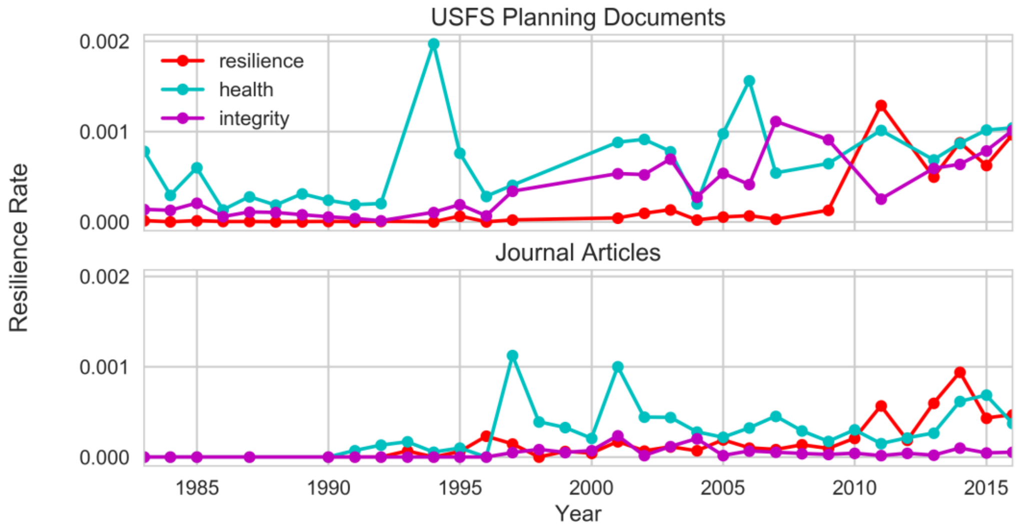

Figure 1: Rate of "resilience" (i.e. resilience, resilient, and resiliency) by context and year compared to the rate of the terms "health" and "integrity"

1.5.2 Q2: Resilience, environmental values, complex systems theory, and environmental change

The rates of environmental value terms (utilitarian and biocentric) have changed over time in both contexts (Figure 2). In scientific journal articles both value rates show a high degree of variability between 1980 and 1994 because there are few documents in the sample from this period. By 1998, and from then on, the value terms rates are relatively consistent across the period and when the use of resilience increased around 2011, they both remain fairly level. In USFS planning documents (FEISs and Forest Plans), however, there do appear to be meaningful shifts in the rates of the value terms. In USFS documents utilitarian terms occurred at a higher weighted rate than biocentric terms between 1980 and 1995 with a relatively wide gap between them. In 1994 the weighted rate of utilitarian value terms declined and the weighted rate of biocentric value terms increased, so that the gap between the two rates narrowed to become almost non-existent and by 2011, the gap between the weighted term rates widened again, but this time with the biocentric term rate much higher than the utilitarian term rate. Complex systems terms have been used in both contexts since the 1980s, but the use trends show relatively little change between the 1980s and 2016. The terms "climate change" and "adapt" have been also been used in both contexts for most of the period, but in USFS planning documents their use increased sharply between 2009 and 2011, and in scientific journal articles their use begins to increase steadily during the same period (Figure 3).

A statistical analysis of these trends reveals possible relationships between the changes in resilience use and changes in hypothesized contextual term rates (Table 2). In USFS planning documents, the resilience use rate is positively correlated with the use rate of "climate change" and "adapt" ($p < 0.001$) and negatively correlated with resilience use from the previous year ($p \sim 0.024$). In scientific journal articles the resilience use rate is positively correlated with climate change adaption terms ($p \sim 0.012$) and resilience use from the previous year ($p \sim 0.001$). The resilience use rate in scientific journal articles is also weakly negatively correlated with the rate of complex systems terms ($p \sim 0.049$).

*Table 2: Multivariate regression models of resilience rate trends by context ($p <0.001$ - ***, $p < 0.01$ - **, $p < 0.05$ - *)*

	Science		USFS	
	Best fit	Complete	Best fit	Complete
Complex systems rate	-0.0348*	-0.0476		-0.043
Climate change adaption rate	0.1301*	0.1471*	0.7172**	0.7346**
Utilitarian value rate		0.0091		0.0026
Biocentric value rate		-6.2093	-113.1284	-127.9582
Lagged resilience rate	0.5026**	0.4947**	-0.1782*	-0.1896*
AIC	-461	-458	-432.1	-430
Adj. R-squared	0.59	0.57	0.95	0.95

In interviews most managers and scientists associated the increased use of resilience to a shift from production, or output oriented, management in the 1980s, to more ecological and holistic approach to management (e.g. longer-term planning, considering broader scales, and ecosystem process and function rather than composition and structure). Scientists and managers also describe this shift as much broader than the context of western forest science and management; but rather, as one agency scientist said, as the result of an "evolution of societal values." Most mangers and scientists also described the awareness of climate change as playing an important role in the increased use of resilience. Many described how the goals and terminology of restoration, for example, are no longer reasonable when changes are acknowledged. A few described resilience as a safe alternative to "restoration," because it avoids setting a problematic baseline (i.e. pre-European), and the political connotations of "climate change." Neither managers nor scientists mentioned the role of complex systems theory directly, but some scientists mentioned associated concepts like the shift to understanding ecosystems as having multiple equilibria or being dynamic complex, and unpredictable.

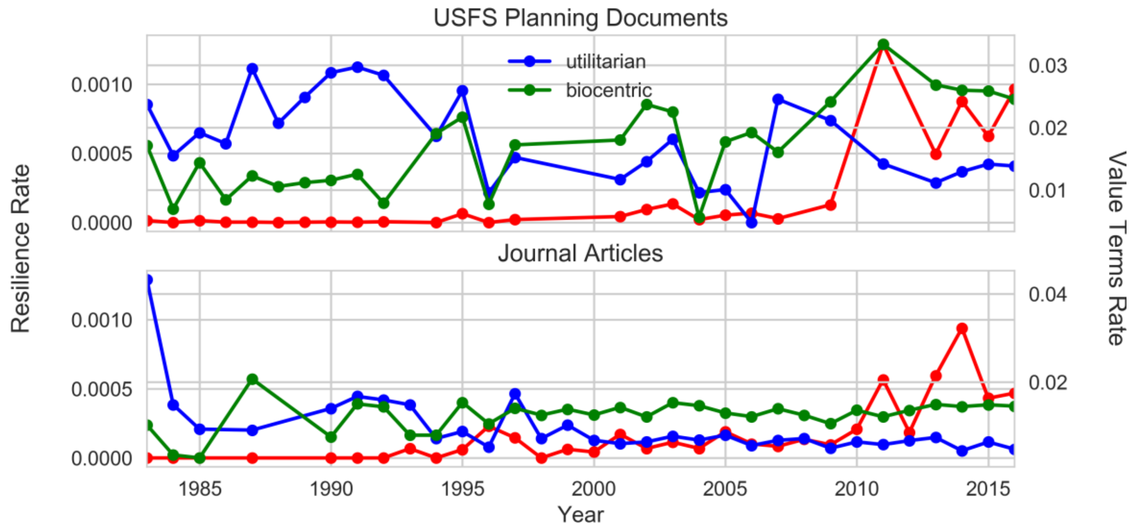

Figure 2: Rate of resilience and biocentric and utilitarian values by context and year

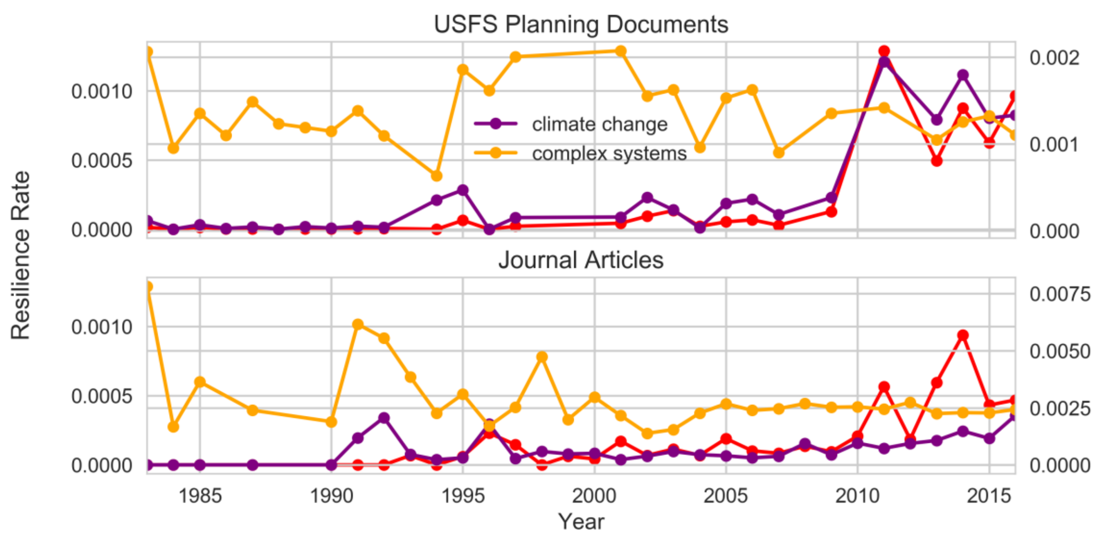

Figure 3: Rate of resilience and complex system terms and climate change adaption ("climate change" and "adapt") by context and year

1.5.3 Q3: Resilience in scientific literature and USFS planning documents

The word resilience (i.e. resilience, resiliency, and resilient) was used a total of 5484 times, 3898 times in USFS planning documents and 1586 times in scientific journal articles. The structural topic model fit to 5484 instances of resilience inferred 39 topics and the twenty most commonly expected topics of the structural topic model demonstrate that resilience use between USFS planning documents and scientific journal articles has similarities, but also differences (Table 3). The topic 'climate change adaption' and 'maintaining ecosystems' are common and shared between scientific journal articles and USFS planning documents. USFS planning documents were more likely to contain the use of resilience in the context of the topics: 'desired conditions', 'invasive species', 'watersheds and water quality', 'impacts of grazing on riparian areas and soil', 'insects and disease', and 'high intensity fires, landscapes'. In scientific articles resilience was more commonly used with the topics of 'fuel reduction by thinning and prescribed fire', 'old growth forest resistance and recovery', 'restoring wildland fire regimes', and the 'risks and benefits of promoting wildfire'.

In interviews, both scientists and USFS managers generally described resilience as a response to change. A few USFS managers offered highly specific interpretations of resilience. One manager told me: "I would define resilience as … if our stands, under our management, are free to grow in the absence of fire, if they're free to grow in a manner that benefits the suite of resources that utilize those habitats, including wildlife" and another suggested that "maybe resiliency is the ability of the landscape to repel non-native invasives." Scientists, on the other hand, offered more general, or theoretical interpretations, like one, who told me "[resilience] is the capacity of the system to regain its characteristic processes and to reorganize following a disturbance." All respondents were wary of the confusion and complexity in defining resilience, many calling it "context-dependent" and a few even subjective. One scientist told me that "a lot of us have pretty different ideas in our minds of what we mean by resilience" and what I heard repeatedly was what one manager told me: "[resilience] depends on where you're talking about." Another scientist told me that "the literature is awash with a pretty vague conflating of resistance and resilience." In addition to resistance, resilience was often directly associated or explained using other terminology, particularly "health", "restoration", and "sustainability".

Table 3: Twenty most common of 39 topics by the statistically associated context

Context	Topic Name	Most Common Words
Shared	climate change adaptation	adaptive, change, strategies, climate_change, climate
	maintain ecosystems	ecosystem, future, maintain, restore_maintain, persist
	system ability to absorb	ability, system, state, absorb, return
USFS	desired conditions	desired_conditions, towards, desired, conditions, dc-veg-
	invasive species	species, long_term, term, short, years, invasive_species
	alternatives	action, better, alternatives, alternative, proposed
	plan direction	plan, direction, plan_components, revised, plan_direction

	watersheds and water quality	watersheds, natural_disturbances, quality, water_quality, water
	sustaining processes	sustainability, current, ecological_processes, integrity, facilitate
	impacts of grazing on riparian areas and soil	riparian_areas, areas, grazing, soil, riparian
	insects and disease	insects_disease, large-scale, historic, disease, large-scale_disturbance
	high intensity fires, landscapes	landscape, large_high-intensity, high-intensity, scale, landscape_scale
Science	fuel reduction treatments	reduction, thinning, fuel, fuel_reduction, treatments
	old growth, resistance	old_growth, growth, old, resistance, relative_resilience
	restoring wildland fire regimes	wildland, wildland_fire, maintaining, restoring_maintaining, fire_regimes
	pine trees	ponderosa, pine, ponderosa_pine, tree, lodgepole
	mixed terms	may, highly, found, levels, environments
	risks and benefits of promoting wildfire	risk, benefits, reduce, wildfire, goal
	research	forest_service, service, research, science, response,
	forest management	national_forests, managers, forests, mixed-conifer, burned

1.6 Discussion

In recent years, the word resilience has proliferated rapidly throughout a wide range of academic fields (Brand and Jax 2007; Xu and Marinova 2013). The precise meaning of resilience for management and policy, however, remains ambiguous. In journal articles published in the last decade, resilience has been described as a descriptive and measurable characteristic that emerges from ecosystem structure (Carpenter et al. 2001); a framework associated with concepts like ecosystem integrity, health, degradation (Ghazoul et al. 2015); and a strategy for forest management in the face of unprecedented change (Millar, Stephenson, and Stephens 2007). It has become particularly common in high-level planning documents about managing fire such as The National Cohesive Wildland Fire Management Strategy, which sets a goal to “restore and maintain landscapes… [that] are resilient to fire-related disturbances in accordance with management objectives” (U. S. Department of Agriculture and Interior 2011; Cissel and Jenison 2015). It is also increasingly used by federal land management agencies in the United States. For example, in the United States Forest Service, where recent analysis suggests that resilience still requires conceptual clarification (Bone et al. 2016).

Carl Folke, a founding member of the Resilience Alliance, recently published a review of the concept of resilience in which he writes:

> Resilience thinking emerged from the discovery, based on observation, that living systems have multiple basins of attraction… [and] has developed into an approach for understanding complex adaptive systems and serves as a platform for interdisciplinary and trans-disciplinary research with an emphasis on social-ecological systems (2016).

This way of identifying the meaning of resilience presents two problems. First, it dehistoricizes and decontextualizes the remarkable inter-disciplinary increase of the use of word in the least several years and the active role of the Resilience Alliance in developing and promoting it (Parker and Hackett 2012). In addition to scientists, resilience has been adopted by a wide range of users including governments, NGOs organizations, corporations, and global financial institutions like the International Monetary Fund and the World Bank, and the way it is defined depends less on a shared theoretical understanding of complex systems, than each group's objectives (Walker and Cooper 2011). Furthermore, common language, as well as scientific and academic language used in land management is always tied to the social context of its use (Williams 1985; Skillen 2015; Hajer and Versteeg 2005; Norton 2005). The objective of this paper, was to attempt to place the increasing use of the word in western US forest and fire management and science within the context of other trends in language to understand its varied meanings within a setting.

Plotting the use of resilience across all western USFS unit planning documents and scientific journal articles on western US forest and fire management between 1980 and 2016 reveals that the word has been used in this context since the 1980s, but only recently—between 2010 and 2016—has its use increased rapidly. Interestingly, the plotted biocentric and utilitarian value term trends of the USFS planning documents appear to show shift from predominantly utilitarian values to predominately biocentric values. This may reflect a well-discussed shift in USFS management from economic-focused management priorities in the 1980s to more biocentric, or ecosystem-focused management priorities following the Northwest Forest Plan and the adoption federal ecosystem management (Skillen 2015; Hays 2006). Shifts that occur at smaller scales may reflect the transitions between US White House administrations; a process which has played an important role in the language, if not the general priorities of federal land management during this period (Vaughn and Cortner 2005). However, statistical analysis of these trends suggests that use of resilience, and its recent increase, in the context of western US forest and fire management and science, is not associated with longer term changes in biocentric values utilitarian values nor complex systems terminology, but is most associated with an increase in the use of the terms "climate change" and "adapt."

Determining the precise timing and origin of the increase in resilience usage, and the driver behind it, is complicated by the time-lags inherent to the policy creation and scientific publication process, and would require a much more in-depth, historical, analysis. The timing of these marked increases, does appear to be later than the timing found in other, broader, bibliometric studies of resilience use, which suggests that resilience may have entered the language of western forest fire management and science later than it did in other contexts and regions (Xu and Marinova 2013). These findings partially conflict with the perception held by many USFS mangers and scientists who connect the increasing resilience usage to a historic shift of USFS, and national values, from utilitarian management toward more biocentric management. It also suggests that resilience use is not associated with complex systems terminology or even with a change in how the stability of ecosystems are described linguistically, including in the scientific literature.

In management documents, resilience is often part of a desired condition (e.g. “a resilient forest”), which suggests that managers are grappling with achieving desired conditions under increasingly hot and dry conditions, and aspects not obvious to more abstract definitions of resilience (Brand and Jax 2007; Davidson et al. 2016). However, both scientists and mangers believe use of the word resilience may be emblematic of an increasing recognition of the limits of human control of ecosystems, a notion found in Holling’s original work on resilience and much of the seminal resilience-thinking literature (Gunderson and Holling 2002; Holling 1973; Holling and Meffe 1996). USFS managers and scientists both expressed concern about the ambiguity of resilience. On the one hand, the ambiguous, but holistic resonance of resilience may be helpful for mangers who are working to balance multiple, and sometimes conflicting interests, under changing conditions. It also appears likely, as a few managers and scientists suggested, that resilience is in some cases a helpful stand-in for more polarizing terms like “climate change” or historically-oriented strategies like “restoration.” These possibilities suggest resilience is more than the emergent result of a coalescing scientific consensus around a scientific discovery of nature (Folke 2016, 2006).

Ultimately, understanding language as dynamic, rather than static, involves recognizing that the meaning of resilience is continually evolving. The evolution of past management terminology, like “sustainability,” “health,” and “ecosystem management” from embraced, to redefined, and in the latter case, even discarded, serve as relevant examples (Norton 2005; Vaughn and Cortner 2005; Skillen 2015). A few recent events offer some clues at how the meaning of resilience may change in the future. The fact that resilience was removed from the final 2012 Planning Rule, and replaced with the word “integrity,” due to public concern over its meaning, does not bode well for the continued use of resilience goals in policy. It should remind scientists, managers, and policy writers of the importance of the public’s perception in discussions about terminology. Another example can be found in high level USFS policy documents. In the most recent 2018 USFS budget justification prepared by the Trump Administration, resilience use decreased dramatically from previous years. This could mean the Trump Administration is intentionally avoiding the term for some political meaning it holds, or that it is already falling out of favor due to its ambiguity.

Perhaps the most important example of recent use is a bill, titled the H.R. 2936 - Resilient Federal Forests Act of 2017 and written by Rep. Bruce Westerman, a Republican of Arizona, that has passed the House of Representatives and is currently being read in the Senate. The word resilience appears twice in the bill—in the title and in the purpose statement—and its stated goal is to “expedite” the environmental assessment process mandated under the National Environmental Policy Act (NEPA) for “return[ing] resilience to overgrown, fire-prone forested lands, and for other purposes.” The description of the bill on the House committee of Natural Resource’s website (https://naturalresources.house.gov/hr2936) describes the goal of the bill as freeing agencies from “overly cumbersome and lengthy environmental processes” to “proactive, healthy forest management,” particularly “thinning the forest [which] helps protect and restore forests while also helping local economies and creating jobs.” The use of resilience appears to be framing forest thinning as a management strategy for forest adaptation rather than “learning to live with wildfire,” which portends further conflict over how resilience is defined.

As scientists, policy makers, managers, and stakeholders work to operationalize this term for federal wildfire management, reconsidering the reasons for the word’s ambiguity may lead to a richer understanding of its meaning. The medium of language is not as reliable or concrete as we may like and as environmental historians have demonstrated, changes in scientific and management language often cannot be separated from broader changes in social relations, material conditions, and collective values (Worster 1994; Merchant 1990). What past disputes over environmental and public land policy ultimately demonstrate, is that environmental policy, although informed and communicated through scientific or technical language, is always about environmental values (Layzer 2011). Attempts to operationalize resilience for land management that do not consider the meaning of words as a result of a social process, and the medium of language as a source of ambiguity, risk continued misinterpretation and may only end in frustration.

Appendices

Appendix A: Interview script

Thank you so much for taking the time to talk with us. As I mentioned in the email, I'm a graduate student at the University of Wisconsin and I'm interested in learning more about land management issues in the Rockies, how foresters and others are responding to changes, and how the concept of resilience is being used. I'm working with a research team to help make new concepts like resilience useful to land managers.

We have a number of ground rules to go over since this is a university research project. First, your participation in this study is completely voluntary, and you can end the conversation at any time. Information in the recording may be used in research and future publications. We'll make sure only approved personnel have access to the recordings, and they will be stored on a password protected computer at UW-Madison indefinitely. You can also choose whether you are willing to be quoted or not. Data will be aggregated and no responses will be identified with your name. I do not expect this interview to have any direct benefits to you. We do hope it will help improve forest management. Although I will take all precautions against any breach of confidentiality, there is a slight risk if any of my files are lost or stolen.

Finally, you may ask questions at any time. You can also contact Dr. Adena Rissman at 608-263- 4356 or adena.rissman@wisc.edu.

If you are not satisfied with the response of the research team, have more questions, or want to talk with someone about your rights as a research participant, you should contact the Education Research and Social & Behavioral Science IRB Office at 608-263- 2320. Great, can I go ahead and turn on the audio recorder? [Turn on recorder, if answered yes] OK, can I use direct quotes from this interview without your name? If you are not sure, you can make a final decision at the end of the interview.

[Interview begins]

- From your perspective, what makes for resilient landscape?
- Tell me about a specific example from your work where resilience is used.
- I've been reading the plans and find it frequently used in management documents (provide examples). What does resilience do for management?

Appendix B: Coding Dictionaries

Table B.1: Utilitarian value term dictionary (Bengston et al. 2004)

benefits_of_timber	tree_harvest	stumpage
bid_price	housing_market	supply_and_demand
commercial	industrial_forest	supply-demand
commodity	industrial_forestry	timber
commodities	industrial_land	timber_dependent
crops_of_tree	industrial_interests	timber_export
tree_crop	intensive_culture	timber
dollars_in_timber	intensive_forest_management	industry
earning	intensive_forestry	timber_job
earnings	intensive_management	timber_loss
economic	intensively_managed	timber_management
economical	log_price	timber_operation
economically	log_export	timber_plantation
economic_analysis	logs_harvested	timber-producing
economic_development	logger	timber_production
economic_effect	logging	timber_sale
economic_growth	lumber_and_pulp	timber_shortage
economic_impact	lumber_consumption	shortage_of_timber
economic_sense	lumber_market	timber_supply
economy	lumber_price	timber_supplies
economies	lumber_product	supply_of_timber
exports	market_price	timber_value
exporter	market_value	timberland
exporting	market_system	tree_farmer
exploited_for_timber	non-market	tree_farming
firewood	nonmarket	tree_plantation
forest_product	monetary	utilization
goods_and_services	monetizing	utilize
grazing_fee	monetization	utilized
harvest_level	plantation	underutilized
harvest_timber	processed_timber	wage
harvest_tree	profits	willing_to_pay
harvesting_timber	profitable	willing-to-pay
harvesting_trees	rangeland	willingness_to_pay
harvesting_of_timber	raw_log	willingness-to-pay
harvesting_of_trees	raw_materials	workforce
timber_harvest	scarcity	

Table B.2: Biocentric value term dictionary (Bengston et al. 2004)

absorb_air_pollutants	ecosystem_restoration	mycorrhizae
absorption_of_pollutants	ecosystem_services	mycorrhizal
air_purifier	ecosystem_structure	nature's_services
air_purify	ecosystem_sustainability	nitrogen_cycle
air_purifying	ecosystem_values	nitrogen_cycling

air_and_water
air_quality
assimilative_capacity
waste_assimilation
aquatic_life
aquatic_zone
breakdown_of_pollutants
acid_drainage
acid_precipitation
acid_rain
biodiversity
bio-diversity
biotic_diversity
ecosystem_diversity
genetic_diversity
landscape_diversity
species_diversity
structural_diversity
biological_diversity
biological_health
biological_integrity
biological_legacy
biological_legacies
biological_processes
biological_systems
biological_wealth
biosphere
biospheric
biota
biotic
binding_of_soil
soil-binding
buffer_strip
buffer_zone
carbon_cycle
carbon_dioxide
carbon_fixation
carbon_sequestration
carbon_sink
carbon_storage
co2_fixation
co2_sequestration
co2_sink
co2_storage
climate_amelioration
climate_ameliorate
climate
ameliorating
climate_buffer
energy_balance
energy_capture
energy_cycle
energy_cycling
energy_exchange
energy_flow
flow_of_energy
energy_flux
energy_transfer
energy_and_material
potential_energy
entropy
environment
environmental
environmental_benefit
environmental_baseline
environmental_cost
environmental_concern
environmental_degradation
environmental_function
environmental_health
environmental_impact
environmental_processes
environmental_quality
environmental_restoration
environmental_services
environtemmental_toxin
environmental_value
environtally_beneficial
environmentally_sensitive
environmentally_sustainable
erode
eroded
erodible
eroding
erosion
eutrophication
exotic_species
extinct_species
extinction
endemic_species
endangered_species
filtration
flood_control
controlling_flooding
flood_mitigating
flood_mitigation
storm_abatement
food_chain
fixation_of_nitrogen
nitrogen-fixing
nitrogen-fixation
nutrient_cycle
nutrient-cycling
nutrient_export
nutrient_flux
nutrient_pool
nutrient_recycling
cycling_of_nutrients
nutrient_uptake
old_growth_corridor
ozone_depletion
ozone_hole
ozone_layer
stratospheric_ozone
pollution
oxygen_production
production_of_oxygen
photosynthesis
radiation_balance
radiation_flux
restoration_ecologist
restoration_ecology
restored_ecosystem
riparian
riparian_area
riparian_boundary
riparian_communities
riparian_system
riparian_zone
revegetate
self-maintenance
self_maintenance
self-replicating
self_replicating
self-sustaining
self_sustaining
siltation
species_abundance
species_loss
species-poor
species-richness
threatened_species
soil_conservation
soil_erosion
soil_formation
soil_maintenance
soil_movement

climate_change
climate_stabilization
climate_stabilizer
climatic
change
climatic_regulation
community_of_life
complex_web
damaging_stream
degrade
degradation
degrading
detritus
downstream_habitat
ecological
ecological_benefits
ecological_communities
ecological_community
ecological_diversity
ecological_functions
ecological_health
ecological_integrity
ecological_processes
ecological
restoration
ecological_services
ecological_values
ecologically_valuable
ecologically
complex
ecosystem
ecosystem_complexity
ecosystem_functions
ecosystem_functioning
ecosystem_health
healthy_ecosystem
ecosystem_integrity
ecosystem_maintenance
ecosystem_processes
ecosystem_resilience
food_level
food_web
forest_health
fragment
fragmentation
fragmented
fragmenting
global_change
global_climate
global_warming
greenhouse_effect
greenhouse_gases
groundwater
ground_water
groundwater_contamination
habitat
habitat_protection
habitat_loss
habitat
fragmentation
wildlife_habitat
fish_habitat
homeostasis
homeostatic
hydrologic_cycle
hydrological_cycle
indicator_species
integrityof_ecosystem
jeopardized_species
keystone_species
landscape_ecology
landscape_ecologist
life-support
life-supporting
life_supporting
life-sustaining
life_sustaining
life-cycle
life_cycle
material_cycling
soil_nutrients
soil_productivity
soil_recovery
soil_stabilization
soil_structure
generation_of_soil
topsoil_loss
unstable_soil
solar_energy
solar_equivalents
solar_radiation
streamside_buffers
stream_sedimentation
trophic_activity
trophic_flow
trophic_functioning
trophic_interactions
trophic_level
trophic_organization
trophic_specialization
trophic_structure
trophic_transfer
trophic_web
unraveling
water_cycle
water_purification
water_purifier
water_quality
water_purification
water_purifier
waterquality
watershed
watershed_stabilization
watershed_stabilizer
wetland_restoration
valuable_wetland
wildlife_habitat
wildlife_population
wildlife_support

Table B.3: Complex systems terms (Grauwin et al. 2012)

self organ*	criticality	multiscale
complex network	ecology	neural network
dynamical system	economics	non linear
econophysics	epistemology	non linear dynami
strange attractor	far from equilibrium	non linear system
synergetics	feedback	nonlinear dynamic
adaptive system	fractal	nonlinear system
artificial intelligence	ising	phase transition
attractor	multi agent	plasticity
bifurcation	multiagent	random walk
chaos	multi scale	robustness
control	multifractal	scaling
social system	stability	synchronization
spin glass	stochastic	turbulence
universality	cell automat	

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